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Range extension of the invasive fish *Xiphophorus maculatus* (Günther, 1866) (Cyprinodontiformes: Poeciliidae) in the upper Magdalena river basin, Colombia

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Abstract. This study reports the expansion of the known distribution of the invasive fish *Xiphophorus maculatus* (Günther, 1866) into the upper Magdalena river basin. The new record comes from a wetland in the Dry Tropical Forest biome in Tolima and represents the first collection of this species from the upper Magdalena river basin. An updated distribution for Colombia is provided.

Key words. South America; Tras-Andean region; Tolima; wetland; Poeciliidae; invasive species.

The family Poeciliidae includes 42 genera and roughly 356 species and is distributed naturally in Africa (including Madagascar) as well as the Americas (Eschemeyer & Fong 2016, Nelson et al. 2016). Currently the subfamily Poeciliinae includes 9 tribes, 29 genera and 273 species (Lucinda 2003, Reztnik et al. 2017). This subfamily contains the genus *Xiphophorus* Heckel, 1848, which has 28 species that occur from northeastern Mexico to northeastern Honduras in streams flowing into the Atlantic (Rosen 1960, Rosen & Bailey 1963, Kallman & Kazianis 2006, Stockwell & Henkanaththegedara 2011, Gómez-Gonzales et al. 2014).

The family Poeciliidae includes some of the smallest vertebrates, and the species are highly polymorphic and have ovoviviparous reproduction (Rosen & Bailey 1963). They show marked sexual dimorphism, with males exhibiting showy color patterns and anatomical modifications such as the gonopodium, which is used to transfer sperm to the reproductive tract of the female (Rosen & Bailey 1963, Rodríguez 1997, Stoops et al. 2013). This modification is used in their taxonomic classification because of its great variation in shape and size (Stoops et al. 2013).

The dimorphism of males of some species of *Xiphophorus* includes the prolongation of the lower caudal-fin rays (Rosen 1960, Rosen & Bailey 1963), and it is used as a diagnostic character for some of them. This modification has permitted the artificial segregation of the species in this genus into those that have the prolongation of the lower caudal-fin rays: *Xiphophorus helleri* (Heckel, 1848) and *Xiphophorus montezumae* (Jordan & Snyder, 1899), among others, and those that have not such as *Xiphophorus maculatus* and *Xiphophorus variatus* (Meek, 1904) (Kallman et al. 2004, Kallman & Kazianis 2006, Gómez-Gonzales et al. 2014).

Poeciliids have successfully invaded diverse aquatic ecosystems on almost all of the continents (Lowe et al. 2000, de Brito et al. 2013, Holitzki et al. 2013). These invasions have been facilitated by their use as ornamental species, and as biological control for mosquitoes (Axelrod et al. 2007, Chandra et al. 2008, McDowall et al. 2010, Ghosh et al. 2010).

In Colombia, 7 species of invasive poeciliids have been reported: *Xiphophorus helleri*, *Xiphophorus maculatus*, *Xiphophorus variatus*, *Poecilia latipinna* (Lesueur, 1821), *Poecilia reticulata* (Peters, 1859), *Poecilia sphenops* (Valenciennes, 1846) and *Poecilia velifera* (Regan, 1914), and all of them are present in the Cauca river basin (Gutiérrez et al. 2010, Gutiérrez et al. 2012), the major tributary from the Magdalena basin. However, for the upper Magdalena river basin, only *P. reticulata* and *P. sphenops* have been found in zoological collections (Villa-Navarro et al. 2006). There are only bibliographic reports for *X. maculatus* from this region, with the only reported locality near Bogotá (Alvarado & Gutiérrez 2002, Gutiérrez et al. 2010, Gutiérrez et al. 2012).

This study reports the expansion of the known distribution of *X. maculatus* into the upper Magdalena river basin, specifically from the natural wetlands of Dry Tropical Forest biome, and constitutes the first record based on collected specimens from that biome.

Sampling was done on 4 June 2015 in the Azuceno Wetland (04°01′09.5″ N, 074°57′23.7″ W; 322 m above sea level [a.s.l.]), which is located in the municipality of Guamo, Tolima Department, Colombia (Fig. 1). This natural wetland is located in the Tropical Dry Forest biome of the upper Magdalena river basin. It is surrounded by a matrix of pastures with a town nearby.

The area of this wetland is permanent and covers 18.8 ha, lacks surface outflows, and fills during the rainy season. The substrate is mud, but turbidity is low and depth does not exceed

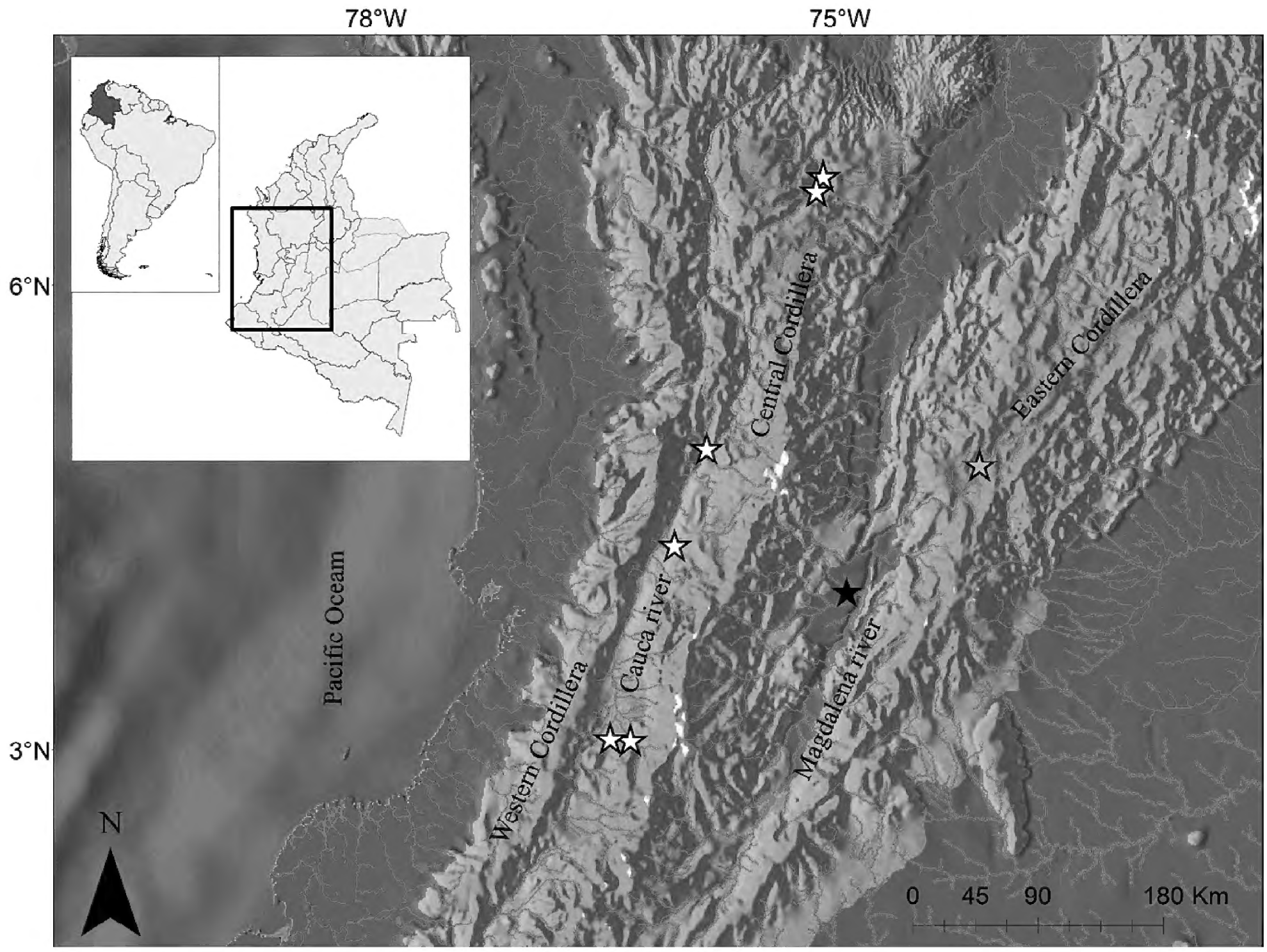

Figure 1. Records of *Xiphophorus maculatus* in Colombia. Black star = Azuceno Wetland, gray star= bibliographic report from ALVARADO & GUTIÉRREZ (2002), white stars = other reports from CP-UCO and IMCN zoological collections.

2 m. Floating macrophytes and submerged grasses are the principal aquatic vegetation present. Shrubs and trees are scarce, and the scarce riparian vegetation forms small isolated patches (Fig. 2).

The pH, conductivity and temperature water were measured using a Schott Instruments Handylab Multi 12/SET. For the other water parameters, 2 L samples were collected in plastic containers and refrigerated for analysis by the Laboratorio de Servicios de Extensión en Analisis Quimico (LASEREX) of the University Tolima. The water quality parameters are given in Table 1.

Fish were collected using portable electrofishing gear (400 V, 1 A), and a small drag seine (2×1×0.05 m). Electrofishing was employed for 15 min in areas where the macrophytes allowed for its use, and was complemented with 5 seine pulls of 3 m length each, passing underneath the floating plants towards shore. Specimens were fixed in 10% formalin and taken in sealed plastic bags, with the corresponding field labels, to the Zoological Research Laboratory (LABINZO) of Tolima University. The research permit was provided by Corporación Autónoma Regional del Tolima (CORTOLIMA) in "Convenio de cooperación interinstitucional 030 del 31 de Julio de 2013", as part of the project: "Formulación del plan de manejo ambiental de los humedales en el departamento del Tolima: Caracterización ambiental de los humedales en zonas bajas del Tolima". Taxonomic identifications were made using keys and diagnoses provided by ROSEN 1960 and ROSEN & BAILEY 1963. Morphological measurements and counts were done following MILLER (1948). All measurements were taken point-to-point with digital calipers on the left side of specimens to the nearest 0.1 mm and are expressed as percentages of standard (SL) and head length (HL). To recognize structures of the gonopodia, 3 adults were cleared and stained (C&S) using procedures outlined by DINGERKUS & UHLER (1977).

The new distribution record was corroborated using the SiB Colombia platform, which includes records from the data bases of the following ichthyology collections: Colección de Ictiología, Universidad de Antioquia, Medellín (CIUA);

Table 1. Physicochemical parameters of the Azuceno Wetland, Guamo municipality, Tolima Department, Colombia.

Parameters	Values
Water temperature (°C)	26
Dissolved Oxygen (mg/L)	3.84
pH	5.55
Conductivity (µS/cm)	233
Alkalinity ($mgCaCO_3/L$)	91
Hardness ($mgCaCO_3/L$)	29
PO_4 (mg/L)	4.3
Suspended Solids (mg/L)	200

Figure 2. Azuceno Wetland, Guamo municipality, Tolima Department, Colombia.

Colección Peces Universidad Católica de Oriente (CP-UCO); Colección Peces Dulceacuícolas, Instituto Alexander von Humboldt, Villa de Leyva (IAvH-P); Instituto de Ciencias Naturales, Museo de Historia Natural, Universidad Nacional de Colombia, Bogotá, D.C. (ICNMHN); Ictiología, INCIVA, Museo de Ciencias Naturales Federico Carlos Lehmann V., Cali (IMCN); and Colección de Peces, Museo Javeriano de Historia Natural "Lorenzo Uribe S. J.", Bogotá, D.C. (MPUJ). In addition, the databases of the following institutions were also consulted: Academy of Natural Sciences of Drexel University, Philadelphia (ANSP); Natural History Museum, London (BMNH); California Academy of Sciences, San Francisco (CAS); Cornell University Vertebrate Collection, Ithaca (CU); Field Museum of Natural History, Chicago (FMNH); Harvard University, Cambridge (MCZ); Muséum national d'Histoire naturelle, Paris (MNHN); Swedish Museum of Natural History, Estocolmo (NRM); Florida Museum of Natural History, Gainesville (UF); National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM); Zoological Museum, University of Copenhagen (ZMUC); and Lund University, Zoological Museum, Lund (ZMUL).

Xiphophorus maculatus *(*Günther, 1866) (Fig. 3)

Platypoecilius maculatus Günther (1866) — Rosen & Bailey (1963).
Platypoecilius maculatus aurata Stoye (1932) — Rosen & Bailey (1963).
Platypoecilius maculatus aurata Stoye (1932) — Rosen & Bailey (1963).
Platypoecilius maculatus cyanellus Meiken (1934) — Rosen & Bailey (1963).
Platypoecilius nigra Brind (1914) — Rosen & Bailey (1963).
Platypoecilius pulchra Brind (1914) — Rosen & Bailey (1963).
Platypoecilius rubra Brind (1914) — Rosen & Bailey (1963).
Platypoecilius maculatus sanguinea Stoye (1932) — Rosen & Bailey (1963).

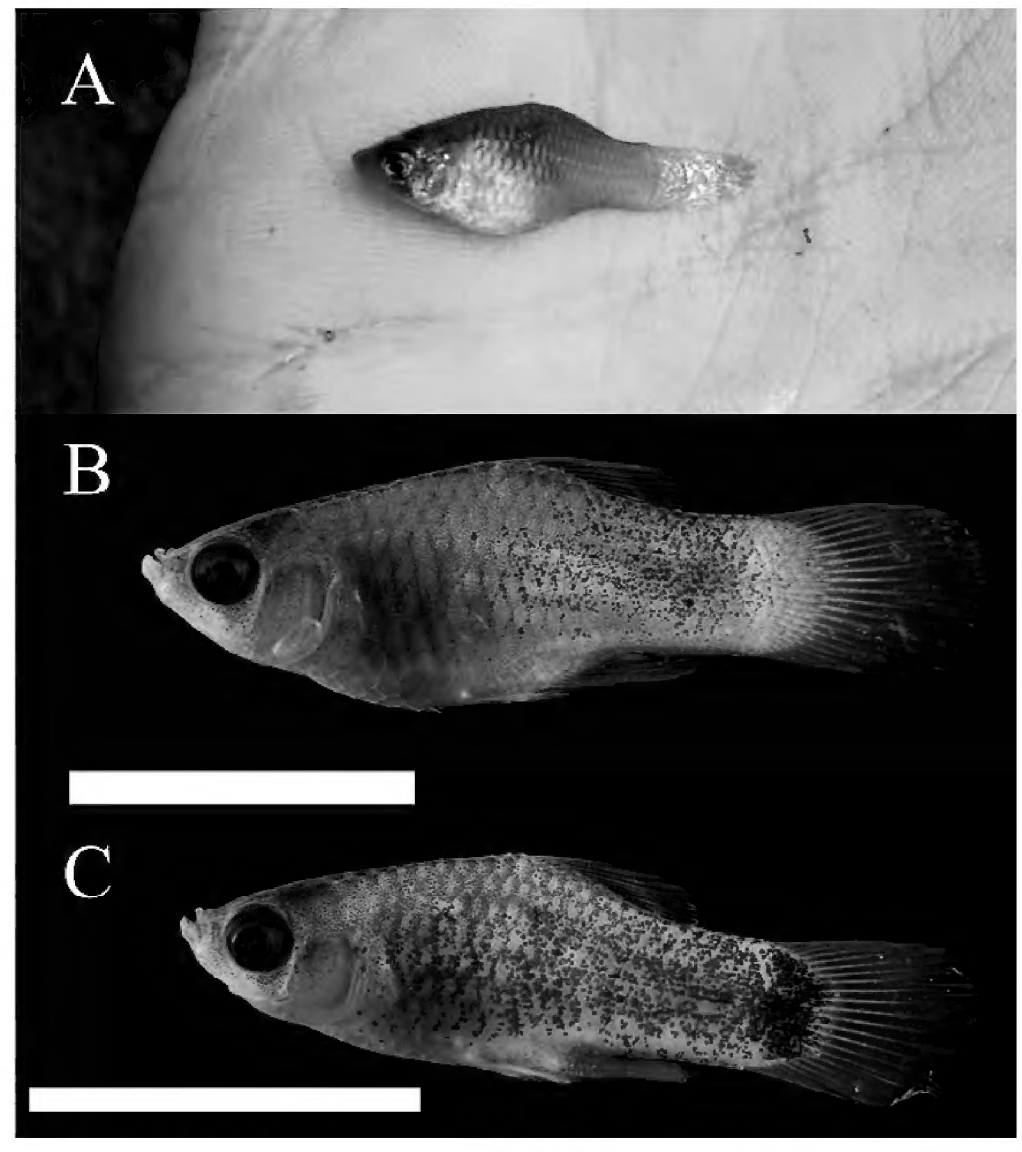

Figure 3. *Xiphophorus maculatus.* A: Live specimen, female. B: Female (CZUT-IC 13910: 19.76 mm LS). C: Male (CZUT-IC 13910: 1602 mm LS). Bar = 1 cm. Photographs A by J.G. Albornoz-Garzón, B and C by J.E. García-Melo.

Figure 4. Distal tip of gonopodium in *Xiphophorus maculatus* (CZUT-IC-13903, 18.84 mm LS). B). Photograph by J.E. García-Melo.

Material examined. All from Azuceno Wetland, Guamo, Tolima Colombia: CZUT-IC 13900, 13, 16.47–24.13 mm SL, (04°01′01.5″ N, 074°57′04.6″ W), 316 m a.s.l., 4 June 2015. CZUT-IC 13903, 36, 15.63–20.85 mm SL, (04°01′15.5″ N, 074°57′15.4″ W), 316 m a.s.l., 4 June 2015. CZUT-IC 13907, 6, 14.63–21.1 mm SL, (04°01′03.0″ N, 074°57′15.0″ W), 320 m a.s.l., 4 June 2015. CZUT-IC 13910, 18, 15.64–19.54 mm SL, (04°01′09.5″ N, 074°57′23.7″ W), 322 m a.s.l., 4 June 2015.

We collected 72 specimens, 48 females and 24 males. The identification as *X. maculatus* was confirmed upon review and corroboration of the diagnostic characters listed by Rosen (1960). These include structures of the gonopodium: distal tip of fifth ray having a small rounded element; posterior region of fourth ray with distal serration well developed that includes four hooks; third ray with long thin hooks. As well as some counts: 22–25 lateral scales and 7–11 dorsal-fin rays (Fig. 4, Table 2). The fleshy palp covering the tip of the gonopodium usually present in species of *Poecilia* was not observed (Rosen & Bailey 1963) (Fig. 4).

Head and body covered with large scales. Dorsal margin of head straight to slightly convex from anterior margin of eye to a vertical above opercle. From there to dorsal-fin origin convex, then gently declined to base of last dorsal-fin ray and then slightly convex to base of caudal fin. Mouth superior, protrusible and not reaching anterior margin of eyes. Eyes large (33.9–39.72% HL) (Table 2). Ventral profile from mouth to pelvic-fin insertions slightly curved, then from base of last anal-fin ray to caudal fin it is slightly concave.

Dorsal-fin rays ii,5,i (2), ii,6,i (11) and ii,7,i (7); the first 2 rays are simple, first shorter than second. Caudal fin rounded. Caudal peduncle long, deep and laterally compressed. Pelvic fins i,3,i (6) and i,4,i (14); In males, first ray simple, and is much shorter than others and ends in swollen, shovel-like structure; third ray is longest, and reaches ⅔ of the length of gonopodium. In females, first ray is not modified at its tip. Pectoral fin i,6,i (1), i,7,i (16) and i,8,i (3). Anal i,5,i (3) and i,6,i (8) (Table 2).

In life, *X. maculatus* is silvery on flanks with black and iridescent blue patches on head, and fins are reddish from base to tips (Fig. 3). In alcohol, males may have melanophores on flanks, when if present are concentrated on caudal peduncle, sometimes covering the bases of caudal-fin rays. Dorsal fin has small dark spots, mostly located on interradial membranes, which are concentrated on distal thirds of branched rays. Caudal fin with melanophores on interradial membranes to point where rays begin to branch; caudal-fin margins lines with thin line of black spots, more evident in larger specimens, almost imperceptible in smaller ones. Pectoral fins with melanophores along edges of rays and membranes. Pelvic fins with melano-

Table 2. Morphometric (mm) and meristic values for specimens of *Xiphophorus maculatus* from the Azuceno Wetland, Guamo municipality, Tolima Department, Colombia.

	Males				Females			
	n	**Mean**	**Range**	**SD**	***n***	**Mean**	**Range**	**SD**
Standard length	9	16.48	14.63–20.70	1.72	11	19.28	16.24–24.13	2.25
Body Depth	9	36.69	34.86–38.98	1.42	11	36.62	33.62–39.04	1.68
Caudal peduncle length	9	24.30	20.46–28.71	2.37	11	23.14	21.49–25.28	1.07
Caudal peduncle depth	9	22.18	19.83–23.56	1.21	11	21.49	20.08–23.28	0.95
Dorsal-fin origin to anal-fin origin	9	36.24	34.26–37.69	1.30	11	35.87	33.46–38.73	1.40
Ventral- fin origin to anal-fin origin	9	13.63	11.50–16.61	1.65	11	15.17	14.08–16.99	0.99
Dorsal-fin length	9	28.78	26.64–32.66	1.80	11	27.48	23.98–29.74	1.90
Gonopodium length/Anal-fin length	9	25.68	21.53–30.92	2.85	11	24.31	22.07–27.71	1.98
Ventral-fin length	9	20.89	17.71–25.16	2.34	11	16.68	14.36–18.23	1.29
Pectoral-fin length	9	21.74	18.84–23.09	1.38	11	19.58	15.56–23.33	2.78
Head length	9	32.87	32.06–33.5	0.49	11	32.04	29.76–33.68	1.21
Snout length	9	39.28	36.76–40.27	1.13	11	36.07	33.87–39.51	1.94
Interorbital width	9	49.26	45.85–52.77	2.13	11	50.23	48.28–51.32	0.95
Horizontal eye diameter	9	36.91	35.11–39.72	1.49	11	35.48	33.90–38.18	1.15
Lateral scales	9	23	21–23		11	21	21–23	
Scale rows between dorsal-fin origin and lateral line	9	4	4		11	4	4	
Scale rows between anal-fin origin and lateral line	9	3	3		11	3	3	
Predorsal median scales	9	10	8–11		11	9	9–11	
Dorsal-fin rays	9	ii.6.i	ii.6.i–ii.7.i		11	ii.6.i	ii.5.i–ii.7.i	
Anal-fin rays	9				11	i.6.i	i.5.i–i.6.i	
Ventral-fin rays	9	i.4.i	i.3.i–i.4.i		11	i.4.i	i.3.i–i.4.i	
Pectoral-fin rays	9	i.7.i	i.7.i–i.8.i		11	i.7.i	i.6.i–i.8.i	

Table 3. Records of *X. maculatus* in Colombia. Asterisk = new report, double asterisk = bibliographic report with approximate coordinates.

Locality	Municipality	Department	Latitude (N)	Longitude (W)	Voucher/reference
Azuceno Wetland, S1*	Guamo	Tolima	04°01′01.5″	074°57′04.6″	CZUT-IC 13900
Azuceno Wetland, S2*	Guamo	Tolima	04°01′15.5″	074°57′15.4″	CZUT-IC 13903
Azuceno Wetland, S3*	Guamo	Tolima	04°01′03.0″	074°57′15.0″	CZUT-IC 13907
Azuceno Wetland, S4*	Guamo	Tolima	04°01′09.5″	074°57′23.7″	CZUT-IC 13910
Unspecified**	Bogotá D.C.	Cundinamarca	04°49′46.1″	074°05′13.9″	Alvarado & Gutiérrez (2002)
La Guinea Stream		Antioquia	06°42′30.8″	075°06′30.4″	CP-UCO 661
Porce River	Yolombó	Antioquia	06°36′44.4″	075°09′06.2″	CP-UCO 662
Cienaga Grande	Caloto	Cauca	03°03′59.4″	076°21′20.3″	IMCN 409
Laguna Cuprecia	Santander de Quilichao	Cauca	03°04′33.9″	076°29′05.0″	IMCN 5184
La Paila River	La Paila	Valle del Cauca	04°19′21.8″	076°04′10.3″	IMCN 3856
Risaralda River	La Virginia	Risaralda	04°56′21.2″	075°51′21.3″	IMCN 3372

phores on third to sixth ray, and concentrated near distal tips. Gonopodium has melanophores concentrated on distal third. Females have melanophores concentrated distal margins of membranes. *Xiphophorus. maculatus* was collected with native species *Hyphessobrycon natagaima* (García-Alzate, Taphorn, Román-Valencia & Villa-Navarro, 2015), *Poecilia caucana* (Steindachner, 1880), *Synbranchus marmoratus* (Bloch, 1795) and *Andinoacara latifrons* (Steindachner, 1878).

This new distribution record enlarges the known distribution of *X. maculatus* in Colombia, increasing from 6 (Gutiérrez et al. 2012) to 7 the number of departments where it is present. Furthermore, it is the first record of this species from a natural wetland in the Dry Tropical Forest biome of the upper Magdalena river basin. It is the first record with associated museum specimens because the previous reports from this region are bibliographic (Alvarado & Gutiérrez 2002, Gutiérrez et al. 2010, Gutiérrez et al. 2012, Sánchez-Duarte 2016 pers. comm).

In aquatic environments, introduction of species is frequently associated with human activities (Ortega 2015), and this seems to be true for exotic poeciliids that are used as biological control agents for diseases vectored by mosquitoes as well as ornamental aquarium fish (Axelrod et al. 2007, Chandra et al. 2008, McDowall et al. 2010, Ghosh et al. 2010, Mousavi-Sabet & Eadgeri 2014).

The cause of the introduction of *X. maculatus* to the Azuceno Wetland is unknown, but since it is an ornamental species, one can infer that it may have been from a local aquarist (Gutiérrez et al. 2010, 2012).

Since invasive species adversely impact the natural community (Mack et al. 2000), such as the alteration of the trophic network and community structure and structural changes to the habitat (Mills et al. 2004, Gutiérrez 2006, Lasso et al. 2014, Magalhães & Jacobi, 2017), some poeciliids have become models for the study of these impacts (MacDonald et al. 2012, Holliztki et al. 2013). Species like *P. reticulata, X. helleri*, *Gambusia holbrooki* (Girard, 1859) and *Gambusia affinis* (Baird & Girard, 1853) modify the macroinvertebrate community through predation, which triggers an increase in the density of the periphyton community and so alters the trophic network (Pyke 2008, Maddern et al. 2011, Stockwell & Henkanaththegedara 2011, Holliztki et al. 2013, Walton et al. 2016). These invasive poeciliids also directly affect native fishes by eating their eggs and juveniles (Ivantsoff & Aam 1999, Rincón et al. 2005, Stockwell & Henkanaththegedara 2011, Schumann et al. 2015), by segregation that results from territoriality (Warburton & Madden 2003) and hybridization (de Brito et al. 2013). Also, it has been shown that aquatic ecosystems suffering human impacts with fish communities with poor species richness are more likely to be colonized by invasive species (Gutiérrez 2006). Those conditions have been successfully exploited by poeciliids since they are favored by their generalist feeding habits (Maddern et al. 2011, Stockwell & Henkanaththegedara 2011).

We infer that the Azuceno Wetland conforms to this scenario because its fish fauna has low richness (5 species), and it is exposed to loss of natural vegetation as a result of human activities in the area. Taking into account the proposal of Gutiérrez et al. (2010) to establish the risk level for invasive species in Colombia, *X. maculatus* is classified as a high risk species because it has been recognized as invasive at a global, regional and national scale. Likewise, there exists information of its life history that allows one to predict negative effects as well as the impossibility of its management once it has established in natural communities. For this reason, we consider it necessary to study the impact of *X. maculatus* not only on the local fish community, but also on the periphyton and macroinvertebrates present in the Azuceno Wetland, with the objective of adequately evaluating the level of the impact it causes on the structure and dynamics of the aquatic ecosystem. Such studies would provide information useful for understanding the ecological implications of this introduction to a wetland in the Dry Tropical Forest biome.

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